GEOLOGIC MAPPING OF HOLDEN CRATER AND THE UZBOI-LADON-MORAVA OUTFLOW SYSTEM.

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Introduction: Geologic mapping in Margaritifer Terra (Fig. 1) yields important new information regarding the inventory, sources, and sinks of water during the Noachian and early Hesperian on Mars [1-7]. Drainage in southwest Margaritifer Terra is dominated by the segmented Uzboi-Ladon-Morava (ULM) mesoscale outflow system that traverses northward along the southwestern flank of the Chryse trough [4-9]. Mapping of lower Uzboi Vallis through Ladon basin highlights the extent and complexity of sedimentary deposits associated with the ULM system [5-13].

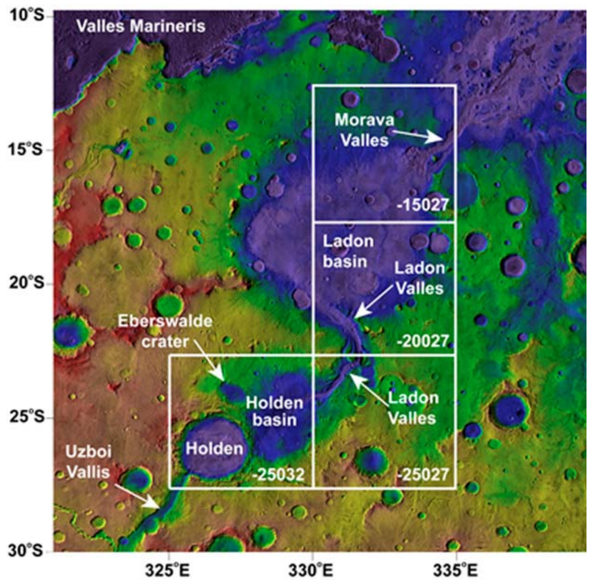

Figure 1. Topography in southwest Margaritifer Terra with major features labeled and showing outlines of maps discussed in text and shown in Fig. 2.

Overview of Geologic Setting: Ongoing mapping identifies a number of units associated with or near the ULM system (Fig. 2). The Early Noachian degraded Holden and Ladon multi-ringed impact basins [14] are the oldest features crossed by the ULM system. These basins imparted considerable structural and topographic influence on the course of the ULM drainage, with incised segments turning to become radial to basin centers. As a result, the ULM system is characterized by deeply incised trunk segments of 15–20 km width, separated by depositional plains partially filling the multi-ringed basins. Formation of these ancient impact basins was followed by prolonged evolution of the diverse cratered upland surface, which may correlate with resurfacing events that have been recognized farther to the east [4]. Crater statistics from the Ladon basin floor and cross-cutting relationships between Holden crater and the ULM system indicate that activity along the system ended by the Early Hesperian [2,3,5,6].

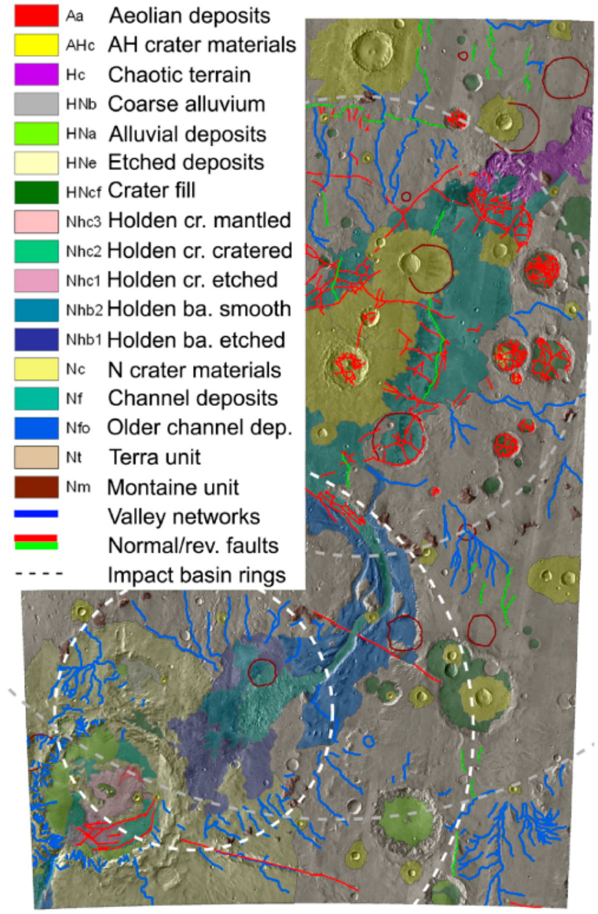

Figure 2. Preliminary draft map of MTM quadrangles -15027, -20027, -25027, and -25032 (see Fig. 1 for context). The Holden and Ladon multi-ringed impact basins, the ULM drainage, and associated tributaries dominate the landscape. Map base compiled using THEMIS daytime IR images.

Deposits in Uzboi Vallis and Holden Crater: The Holden crater rim blocked the previously through-flowing Uzboi Vallis segment of the ULM system. Back-flooding in Uzboi Vallis created an extensive and deep lake that rapidly drained into Holden crater after it overtopped and breached the rim at –350 m elevation. Longitudinal ridges on the floor of Uzboi may relate to scour associated with longitudinal vortices. Some deposits in Uzboi are relatively crudely bedded and are best preserved in embayments and alcoves, where they were protected from high-magnitude drainage into Holden crater (Fig. 3). Other deposits are thin and occur near the basin margin at –350 m. The floor and walls of Uzboi reveal little incision, implying little activity following the breaching of Holden's rim.

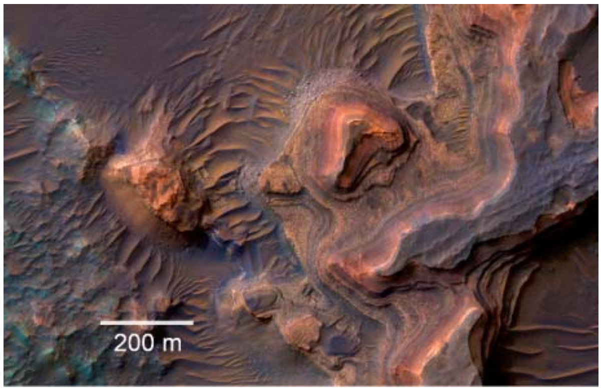

Figure 3. Subset of HiRISE PSP_010329_1525_RGB showing relatively coarsely bedded layers on the lower Uzboi Vallis floor. North is toward the top of image.

As water impounded in Uzboi drained into Holden crater, it eroded pre-existing, finely bedded deposits and emplaced a series of overlying, unconformable, coarsely bedded deposits on the crater floor. The older bedded deposits on the floor of Holden are more than 150 m thick, consist of three members, are phyllosilicate-bearing, and were likely emplaced as distal alluvial or lacustrine deposits fed by internal drainage from the crater walls [3]. High-magnitude discharge from Uzboi emplaced tens of meters of boulder-rich, alluvial deposits near the entrance breach and likely grade upwards and distally into lacustrine sediments deposited in a short lived, shallow lake [3].

Ladon Basin: The floor of Ladon basin is relatively flat (maximum relief 0.27 km over 350 km) and slightly higher in elevation than the floor of Holden crater. Discharge down Ladon Valles appears to have mantled much of the basin floor with sediments, and HiRISE images confirm the presence of extensive and finely layered deposits (Fig. 4). Occurrence of these layered deposits, which may be exposed in the walls of some craters excavating the basin floor, suggest that multiple depositional events contributed to infilling. CRISM data reveal phyllosilicates associated with at least some of these layered deposits [15], and THEMIS data hint at chloride deposits in one part of the basin [16]. The lateral extent of the beds and occurrence of phyllosilicates implies that they may have been deposited in a large, shallow lake controlled by the elevation of the outlet to Morava Valles to the northeast. If that is the case, then the occurrence of chlorides might be consistent with a terminal phase of the lake following late discharge from Ladon Valles.

Summary: The southwest Margaritifer Terra region is dominated by the ULM outflow system that created large channels and extensive layered deposits of mostly late Noachian to early Hesperian age. Deposits within Uzboi Vallis and Holden crater record lacustrine episodes of differing character and duration that may be contemporaneous with extensive alluvial or lacustrine deposits filling nearby Ladon basin and Eberswalde crater. These deposits likely require large inventories of surface water and active cycling of water between the surface and atmosphere as precipitation, implying that conditions were much more clement, and possibly habitable, during emplacement.

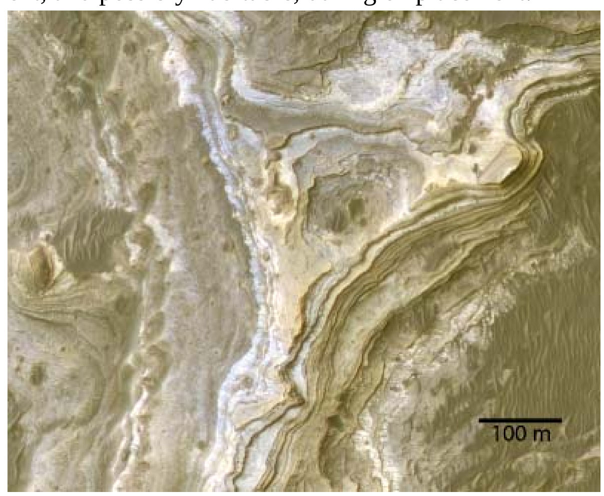

Figure 4. Subset of HiRISE PSP_006637_1590_RGB in Ladon basin near the mouth of Ladon Valles. Extensive, finely bedded deposits are widespread, and at least some incorporate phyllosilicates [15] and possibly chlorides [16]. North is toward the top of image.

References: [1] Grant J. A. (2000) *Geology, 28*, 223–226. [2] Grant J. A. and Parker T. J. (2002) *JGR, 107*, 10.1029/2001JE001678. [3] Grant J. A. et al. (2008) *Geology, 36,* 195–198. [4] Grant J. A. et al. (2009) USGS Sci. Inv. Map 3041, 1:500,000. [5] Irwin R. P. III and Grant J. A. (2009) in *Megafloods on Earth and Mars*, Burr D. M. et al. (eds.), Cambridge Univ.Press. [6] Grant J. A. et al. (2009) in *Lakes on Mars*, Cabrol N. A. and Grin E. A. (eds.), Elsevier (in press). [7] Saunders S. R. (1979) USGS Misc. Inv. Series I–1144, 1:5,000,000. [8] Parker T. J. (1985) M.S. thesis, Calif.State Univ. [9] Parker T. J. (1994) Ph.D. thesis, Univ. of Southern Calif. [10] Pondrelli M. A. et al. (2005) *JGR, 110*, E04016. [11] Moore J. M. et al. (2003) *GRL, 30* (24), 2292. [12] Malin M. C. and Edgett K. S. (2003), *Science, 302*, 1931. [13] Moore J. M. and Howard A. D. (2005) *JGR, 110*, E04005. [14] Schultz P. H. et al. (1982) *JGR, 87*, 9803–9820. [15] Milliken R. E. et al. (2008) *Geol. Soc. Am. Prog. With Abs*, Abstract 134-1. [16] Osterloo M. M. et al. (2008) *Science, 319*, 5870, 1651–1654.